Demonstrating Sustainable Solutions by Applying an Integrated Modelling Approach

Chris Barker[1], Bob Armstrong[2], David Balmforth[2] and Steve Kenney[2]

[1] YWS and [2] MWH

Abstract

The Ripponden sewer network is subject to a large amount of infiltration during winter, resulting in high levels of dry weather flow to Ripponden Wood WwTW. This causes the storm tanks to remain full for most of the period between September and March in a typical year resulting in excess storm flows discharging directly to the river.

An integrated modelling study was undertaken using the available environmental data to continuously model the flows and qualities in the network, WwTW and river. This allowed an examination of the current operational regime and a realistic appraisal of appropriate solutions.

The study demonstrated that the intermittent discharges do not have a significant effect on the water quality and only small amounts of work was needed at the WwTW.

1. Introduction

Ripponden Wood WwTW is built next to the river Ryburn in a steep Pennine valley and serves a population of around 5000. The brief from YWS was to ensure the works met the requirements of the Urban Wastewater Treatment and Freshwater Fish Directives which include a tightening of the final effluent ammonia consent. In addition, the works suffers from a very high level of groundwater infiltration into the contributing sewerage catchment which leads to a continuous spill of dilute sewage from the storm tank for several months of the year. Investigations in the catchment have shown the infiltration to be widespread and not amenable to economic resolution.

The current full flow to treatment (FFT) at Ripponden Wood WwTW is 30 l/s. The maximum flow to the inlet works is approximately 90 l/s. Flows in excess of this spill from a CSO situated just upstream of the works. In summer the storm tanks operate conventionally; spilling during wet weather events with emptying during the intervening dry periods.

In winter, however, due to the high levels of infiltration, FFT is exceeded for long periods so that the storm tanks remain full for most of the period between September and March in a typical year. These flows then discharge directly to the river.

The works inflow records show that dry weather flows in winter are substantially higher than in summer. This is due to increased infiltration which is over 400l/h/d in the winter. Investigation of the sewerage network shows that this increased infiltration is distributed across much of the sewerage network and a substantial part may occur in private drains. Conversely there were no specific isolated lengths of sewer that could be particularly attributed to high winter infiltration.

Traditional solutions to this problem would normally provide enhanced treatment capacity and an increase in the flow to full treatment (FFT). Figure 1 shows that even if FFT is increased at the works the spill duration and frequency of the storm tanks is unaffected. Data also indicates that there is a clear correlation between rainfall, river flows and sewer flows in this catchment (Figure 2).

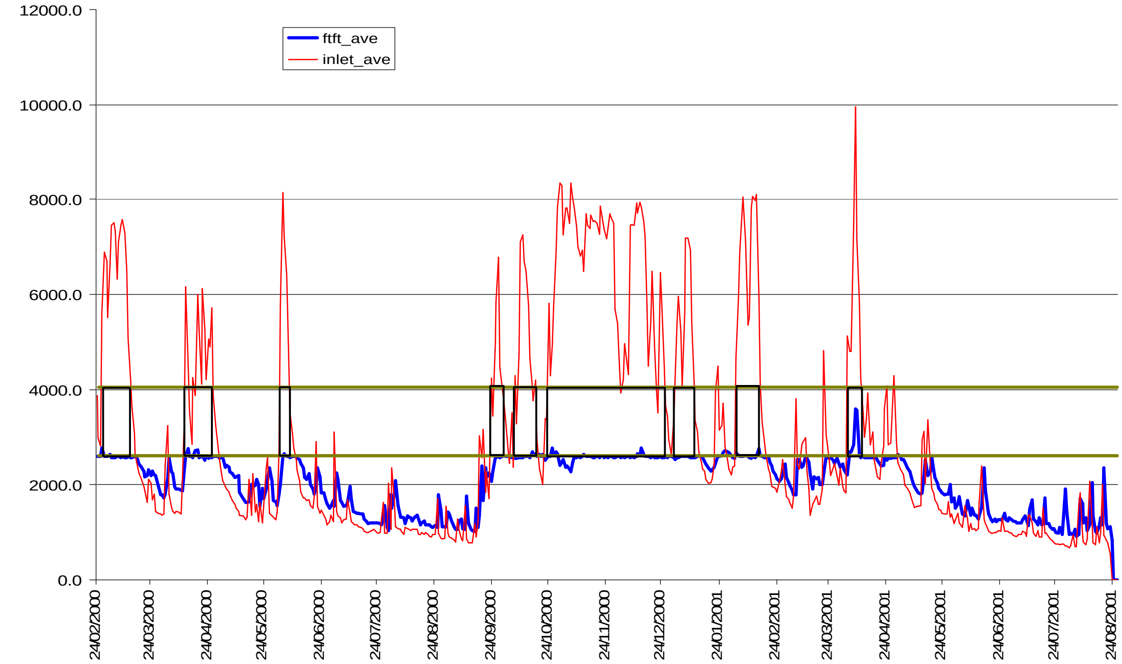

Figure 1: Impact of Increased FFT on Storm Tank Spill Frequency

Other options considered included:-

Rehabilitation of whole sewer network to reduce infiltration	➢ Not feasible
Increased storm tank storage capacity	➢ A conventional storage solution for the storm tanks was shown to be impossible from existing data as the operator would not be able to empty the tanks
Combination of increased FFT and storage	➢ Even with an increased treatment flow the works still require large storage

With the knowledge gained of the system, it was suggested it would be worth investigating whether the spills from the storm tanks (because they only occur only during periods of high river flow), did not constitute a threat to river quality. This further analysis would be achieved by an integrated modelling approach combining network spill with continuous simulation of river flows, sewer flows and final effluent.

If this proved to be the case then it would offer a viable alternative to the traditional solution.

2. Integrated Catchment Modelling Approach

Figure 2 shows a record of river flow and associated rainfall for the River Ryburn Gauging Station upstream of Ripponden. A clear correlation can be observed between rainfall, river flow and works flows. This is to be expected when there are strong groundwater components to river flows which also affect the inflow and infiltration to the sewer system.

The consequence of this correlation is that storm spills to the river during the winter months occur at times when the river flows are high, thus affording greater dilution than with similar spills during summer months. Moreover, the pollutants in the storm flows in the sewer will also be more dilute because of the increased infiltration flow. It is, therefore, possible that the impact from such spills will be much less than might be expected from similar discharges were they to occur in summer.

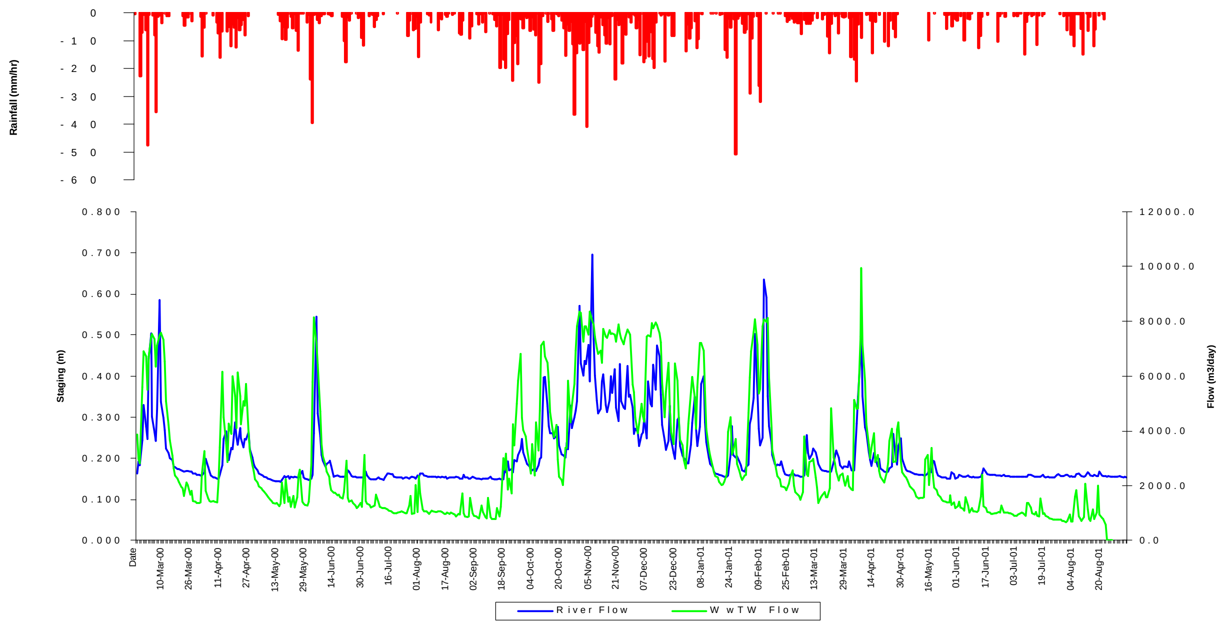

Figure 2 Correlation between River Flow, Inlet Works Flow and Rainfall at Ripponden

To evaluate whether the impact from storm spills and final effluent at Ripponden Wood WwTW for summer and winter months was acceptable use was made of the Urban Pollution Management (v2) standards for intermittent discharges .

A recently completed UPM Study concluded that the River Ryburn would meet Fundamental Intermittent Standards (FIS) during summer months. This study took into account the effects of the discharges from the CSOs, storm tanks and the WwTW final effluent. The modelling for this study was undertaken using stochastic UPM modelling which is considered conservative as correlation between flows is not taken into account.

3. Modelling Strategy

This study was undertaken to understand the whole impact of the works taking the clear correlation of flows in the system into account. The UPM modelling undertaken using the stochastic Simon Tools package had shown compliance with the Sustainable Cyprinid FIS standards given in the UPM2 procedure using HydroWorks for the network inputs. In order to model flow correlation this model was transferred to InfoWorks. A check of the model calibration using both ‘full period short term flow data’ and ‘historical WwTW’ data was undertaken to ensure the model represented the long runoff tails and high winter infiltration. It was not possible to set the model up to represent all observed conditions so sensitivity analysis was undertaken and the conservative model set-up was adopted to for the study. The model was already calibrated for water quality but checks were made on model stability for continuous simulation simulations.

River boundary water quality data was taken directly from the UPM study and was provided by the Environment Agency.

To generate the river flow data a catchment run-off model was created in MikeBasin using the Nedbør Afstrømnings Model (NAM) produced by the Danish Hydraulic Institute (DHI).

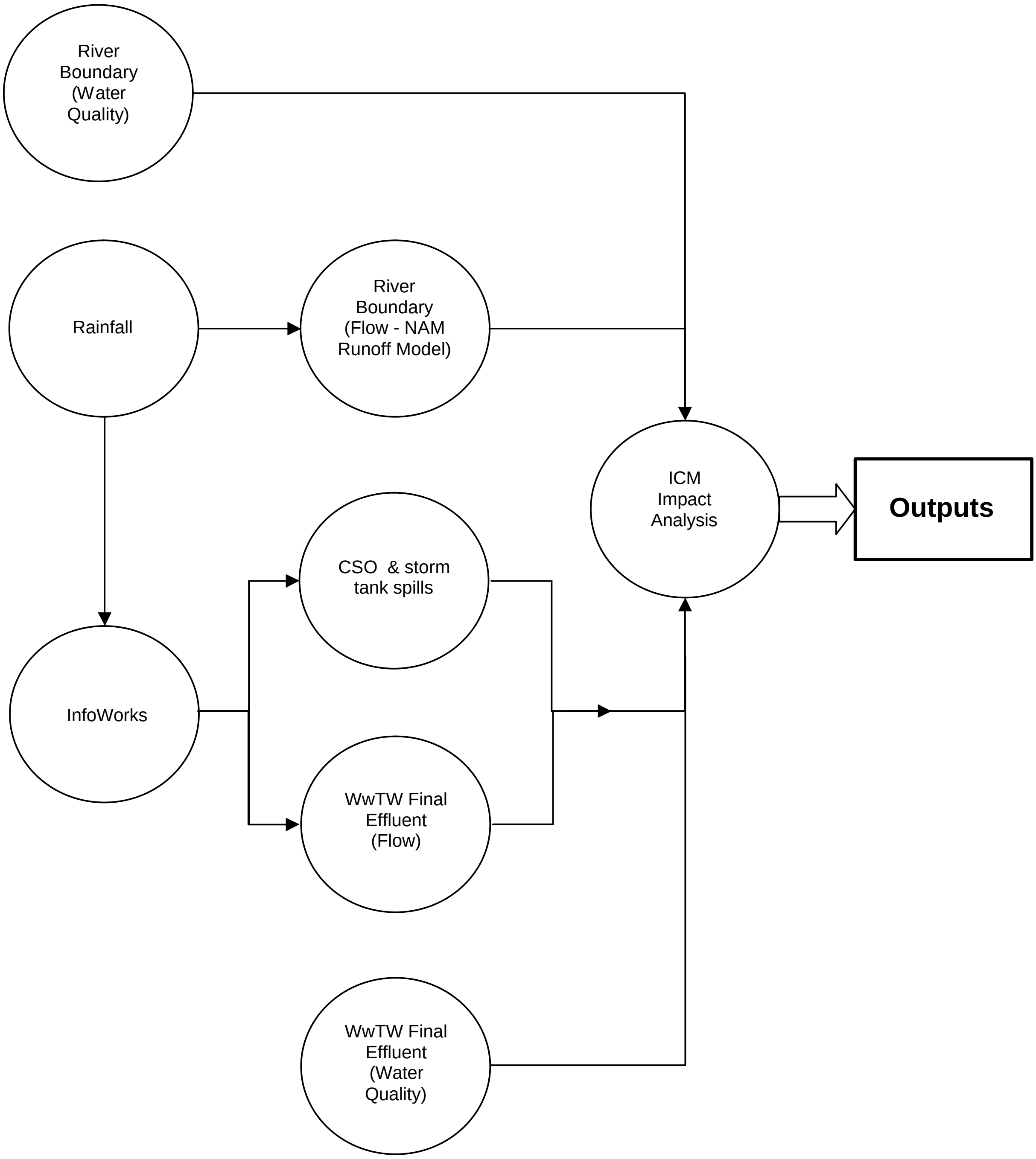

Figure 3: Modelling Overview

Final effluent water quality data was generated from compliance sampling results and a distribution generated using a methodology provided by the EA. The final effluent flow data was taken from the InfoWorks model.

Rainfall was taken from a series produced in the UPM, and the same series used in simulating the InfoWorks and MikeBasin models.

Finally all the inputs were bought together using a mass balance analysis, due to the large datasets generated this analysis was undertaken in Access. A combination of database queries and data import programmes were used to carry out the mass-balance, calculate unionised ammonia concentrations and count the number of failures of a particular standard.

4. Results

Simulation of the existing situation showed that the river complied with high percentile BOD standards but failed the ammonia standards. Having identified that only the ammonia standards were being breached, further scenarios were run to determine the cause of the failure. More detailed modelling of the storm tank process was carried out such as applying a 60% settling efficiency to the storm tank; this had the effect of reducing the number of BOD failures by 30% but made no difference to the number of ammonia failures.

A further scenario looked at the effects of removing the final effluent flows from the analysis. This indicated that the final effluent was responsible for the majority of the failures of the ammonia standards.

Determining the relative impact of the CSOs and the storm tanks was also assessed. This showed that the storm tanks were responsible for a large proportion of the BOD failures but a tiny number of the ammonia failures. The CSOs had a small contribution to the number of overall failures.

Further sets of scenarios were then investigated to determine the effects of changes to the consent for final effluent quality.

The analysis looked at the effects of applying a proposed consent of BOD 25mg/l and ammonia 7mg/l. The effects of tightening the proposed consent to BOD 25mg/l and ammonia 6mg/l were also investigated.

Further analysis was also carried out on the effects of increasing the flow into the works to 122 l/s and the flow to full treatment to 60 l/s.

It was shown that an improvement to the final effluent quality to a 25:7 standard would comply with standards for BOD and FIS standards. The tightening of ammonia standards to 6 mg/l provided a good pass of un-ionised ammonia standards as well as the total ammonia high percentile standards.

An increase in the flow to the works does not show a significant improvement in terms of compliance with ammonia/un-ionised ammonia standards but it does improve compliance with BOD standards.

5. Conclusion

This is the first water quality study undertaken by YWS which has used continuous simulation for the river, sewer network and WwTW for investigating the impacts of intermittent discharges. It has only been possible to apply these approaches to the catchment as there was good quality data available for all aspects of the system. This study has been assembled at relatively short notice using the data that was readily available. The short time-scale has required that a conservative approach be applied in the modelling in order to produce results within a practical timescale.

The sewer modelling has by necessity over estimated infiltration. The storm tank model doesn't contain a settling efficiency and consequently over predicts the BOD concentrations in the spills. The run-off modelling ignored the impacts of the operation of the three reservoirs in the catchments and consequently under-estimated the low flows in the river.

The work has shown that the standards most under threat are the ammonia related standards and that the prime contributor to the number of failures is the continuous final effluent quality.

The frequent operation of the Ripponden Wood WwTW storm tanks in wet weather does not impact on BOD WQ standards as there is sufficient dilution in the River Ryburn to prevent standards from being breached.

The modelling shows that the major impact on river quality is from the ammonia discharges in the Ripponden Wood WwTW final effluent.

The option of keeping the flows to the works as at present and consenting the works to an ammonia standard of 7 mg/l would produces a pass of the FIS ammonia standards. Increasing the FFT at the works would considerably reduce the BOD impacts on the River Ryburn but would not improve the number of ammonia/un-ionised ammonia failures.

Applying an integrated catchment modelling approach, we were able to demonstrate that the spills from the tanks occur mainly during periods of high river flow, and subsequently do not constitute a threat to water quality. This removed the need to increase the works hydraulic capacity as it offers no environmental benefit.